Nordic Mission to Planet Earth

Preface

In 1492 Columbus discovered America. At that stage of man's knowledge of the world around him the discovery was an event of huge significance. Now, 500 years later, we are on the threshold of new, major advances in the exploration of our planet.

This year, 1992, is the International Space Year, the year when we will try to increase our understanding of vital facets of the Earth´s environment, with the help of disciplines including space technology, under the theme "Mission to Planet Earth".

The aim of this brochure is to give a general background description of both the International Space Year and remote sensing technology, and the ways in which this technology can be used as a tool for studying and monitoring the Earth's environment.

In the brochure the Nordic countries which are participating in the International Space Year briefly present aspects of their remote sensing activities. The presentations give practical illustrations of various applications of remote sensing technology.

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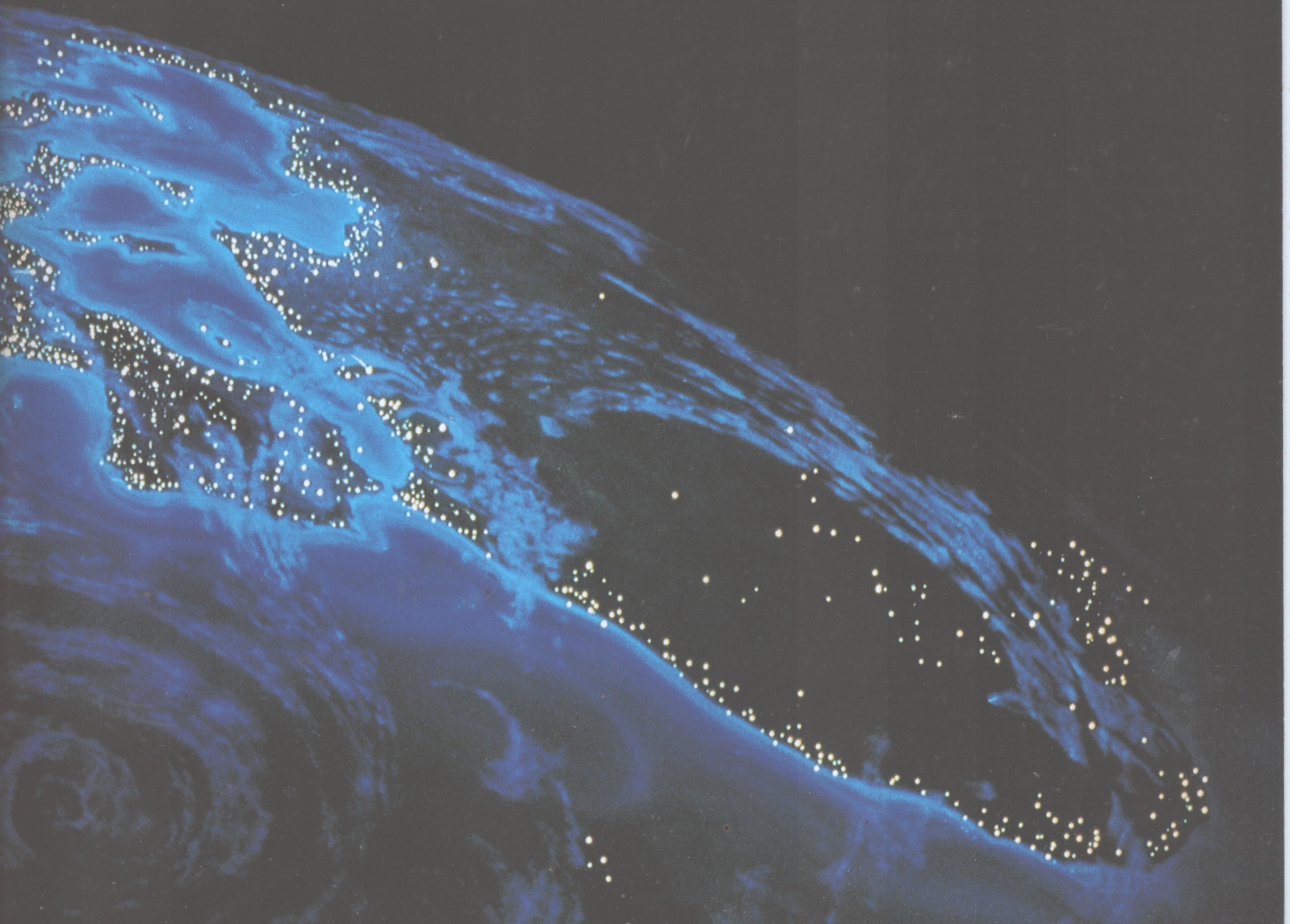
The Earth – our only Home in Space

As a result of advances in many fields of technology, man is able to influence Earth's development. We can either utilize our knowledge to channel development in a positive direction or we can misuse the potential that this knowledge offers us.

More and more people are beginning to realize the inherent dangers for our environment of an insensitive and thoughtless exploitation of the Earth's resources and of a short-term view of the consequences of human activities. For example, the use of fossil fuels has resulted in an increased concentration of so-called "greenhouse gases" which can lead to global heating. With higher temperatures the Polar ice masses can start to melt. This in turn can cause the sea level to rise with widespread flooding as a result.

Agricultural, forestry and industrial activities, methods for handling refuse and transport systems have all affected the ecological system on land and along coastal areas, with serious consequences for biological productivity, water resources and the chemistry of the surrounding atmosphere. The effects of freon gases on the protective ozone layer are well known.

Changes in the global environment cross over national boundaries as well as boundaries between fields of research.



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Mission to Planet Earth

The realization of the effect of the increasing environmental changes that are taking place on our Earth and the understanding of the unique possibilities that space technology offers for global monitoring, were key factors behind the international initiative to name 1992 the International Space Year with the theme Mission to Planet Earth.

Our knowledge of the Earth as a global system comprising land, oceans and atmosphere linked together by hydrological and biochemical processes and energy exchange must increase. Many important pieces in the puzzle must be found before we can understand and explain these mechanisms.

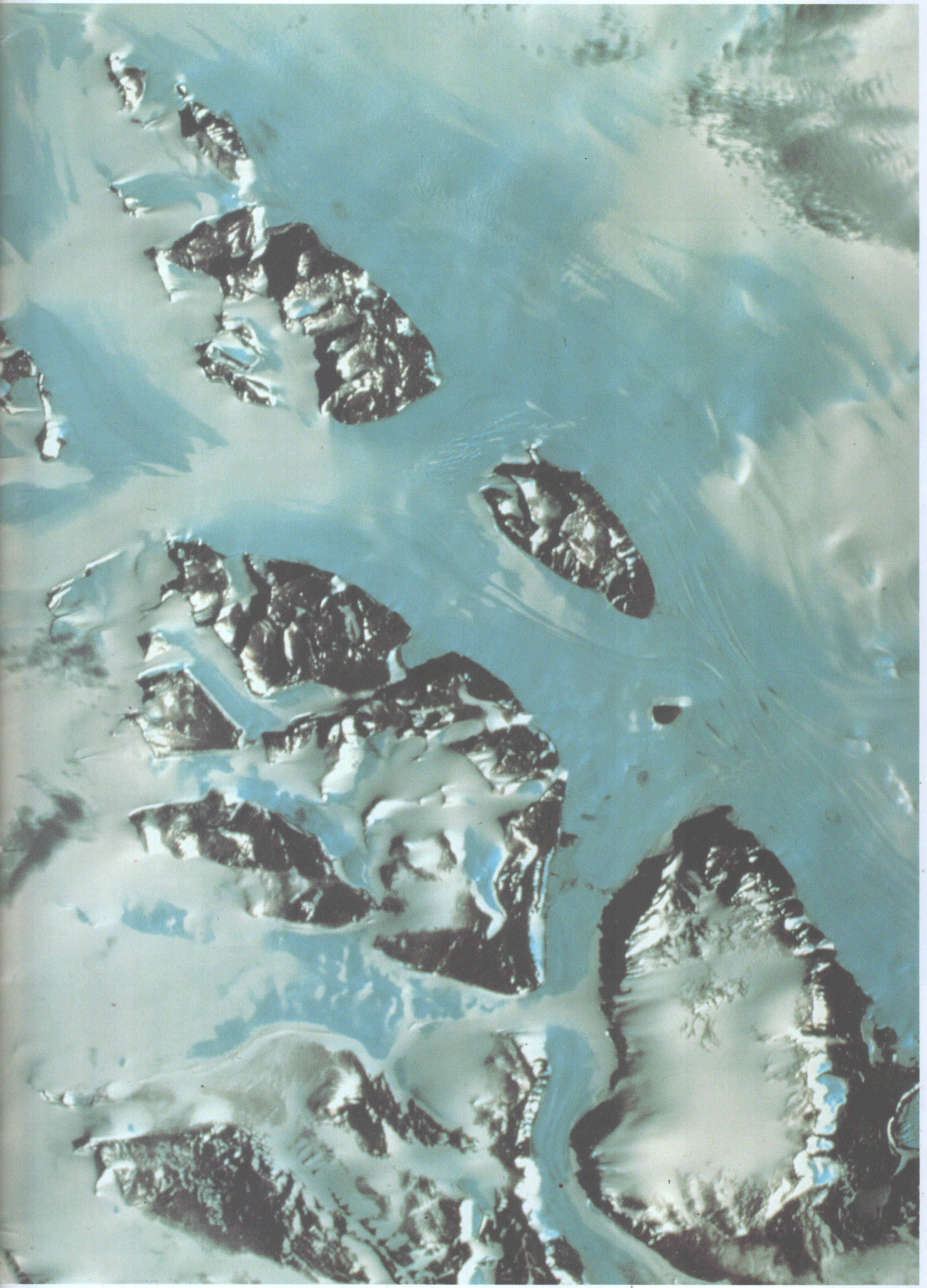
The overall aim of the International Space Year is to demonstrate and arouse interest in the possibilities offered by space technology for global and regional monitoring of the environment and to gather research scientists from industrialized and developing countries in an international, interdisciplinary cooperation, focused on vital environmental questions.

More than twenty-five national space organizations, from Australia and India in the south to the Nordic countries in the north, from China and Japan in the east to the American continents in the west, are currently collaborating on a large number of projects. The European Space Agency, ESA, is very actively involved in these activities. In addition, a large number of national projects are being carried out. Major international bodies, such as the United Nations and the World Meteorological Organisation, are participating as also is EUMESAT which manages the European weather satellites.

Information about the Earth and the atmosphere that can be obtained from the analysis of data captured by satellites is also an important input to programmes such as the International Geosphere – Biosphere Programme (IGBP), which is being carried out by the International Council of Scientific Unions, and to the 1992 United Nations conference on The Environment and Development.

Summer picture from MacRobertson Land, Antarctica.

©CNES



Earth Observation Satellites

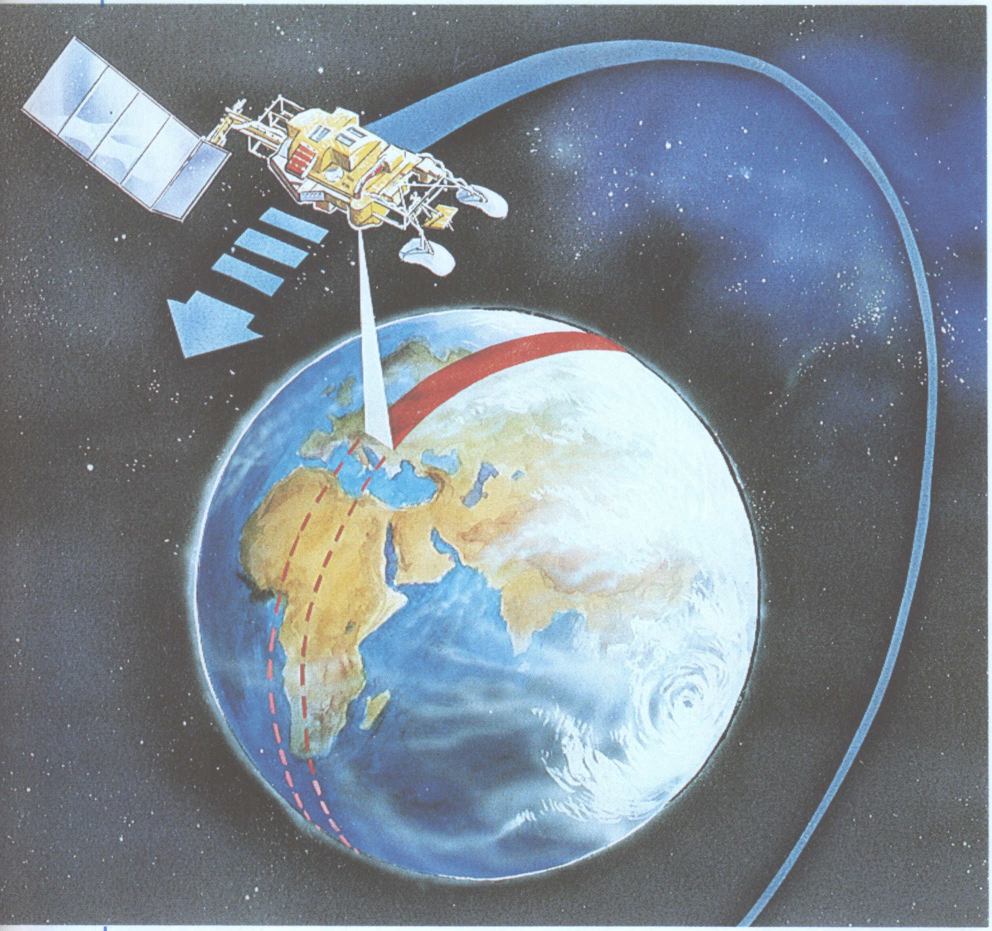
The photographs of Earth taken by the first astronauts gave a first indication of the potential of space technology for monitoring conditions on Earth.

The first, experimental meteorological satellites were launched as early as 1960 and the first civilian high-resolution Earth observation satellite was launched in 1972. This was the first satellite in the American Landsat series.

Since then development has been rapid and many countries have launched their own Earth observation satellites or cooperated with other countries in such endeavours. The French SPOT series of satellites, for example, was developed in cooperation with other countries including Sweden. Monitoring and control of the satellite, as well as reception of the data on the ground, takes place at the ground receiving station at Esrange close to Kiruna in the far north of Sweden.

The latest in a series of Earth observation satellites is the European "all-weather" satellite ERS-1 which has been developed under the aegis of ESA as a cooperative project with the participation of i.a. Denmark, Norway and Sweden. ERS-1 was launched in July 1991 on an Ariane rocket from the space centre in French Guyana. Equipment onboard the satellite includes radar sensors which make it, in contrast to other civilian satellites, capable of capturing data in darkness and through cloud.

The main ground station for ERS-1 is at Salmijärvi close to Kiruna in Sweden. Radar data from this satellite is also received by Tromsø Satellite Station (TSS) in Norway. A worldwide network of receiving stations for ERS-1 data has been established.



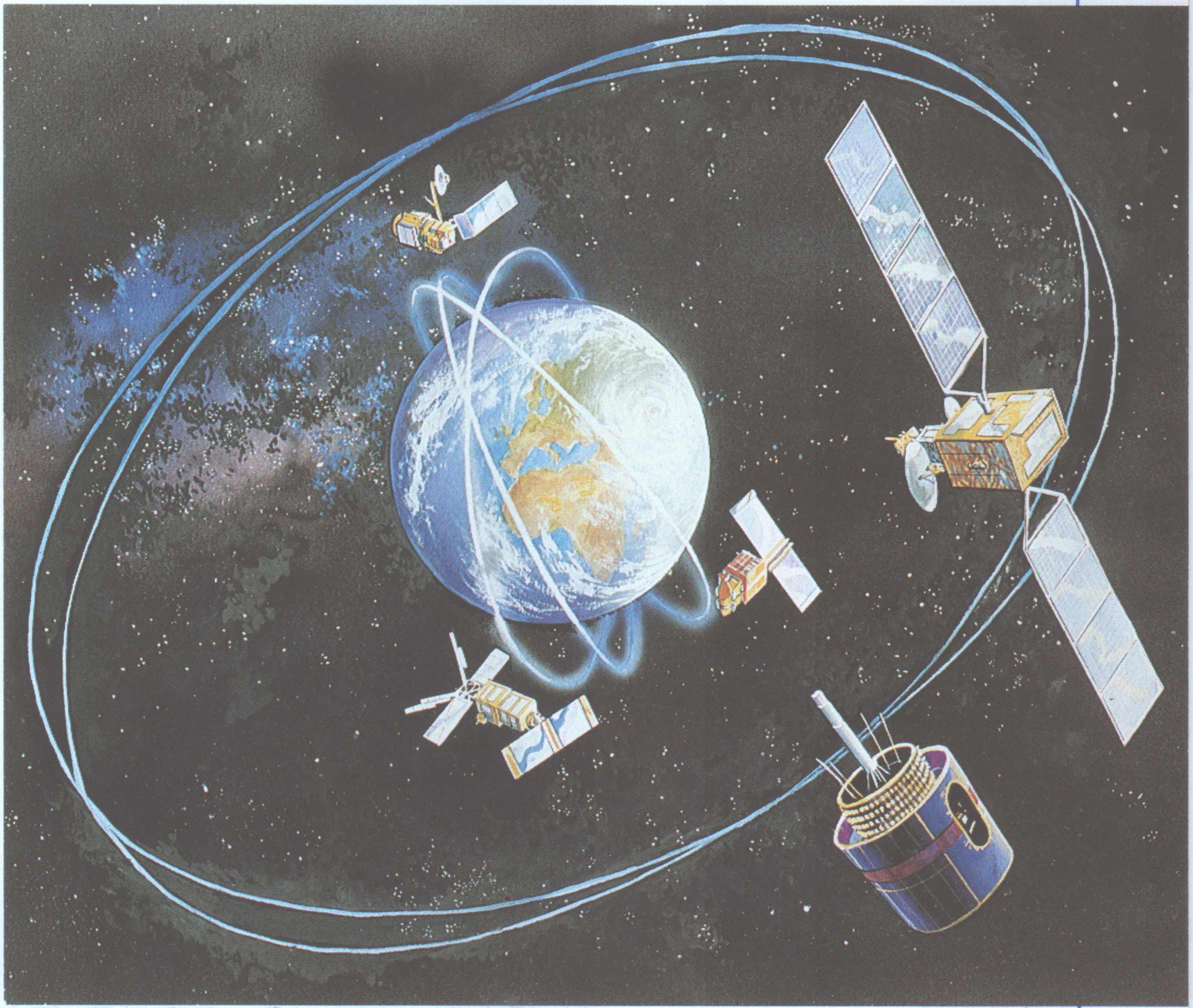
The instruments onboard remote sensing satellites register the surface of the Earth in swaths. The width of these swaths varies from satellite to satellite and depends on the type of sensors on the satellites and the orbit. A Landsat satellite registers a swath which is 185 kilometres wide; the SPOT satellite, which has two instruments, registers two swaths each 60 kilometres wide; and the swath registered by the ERS-1 satellite is 100 kilometres wide.

Satellite Orbits

Meteorological and communication satellites (including TV relay satellites) are placed in geostationary orbit, 36,000 kilometres above the Equator. They follow the rotation of the Earth and thus appear to stand still over a geographic location. Hence the term "geostationary".

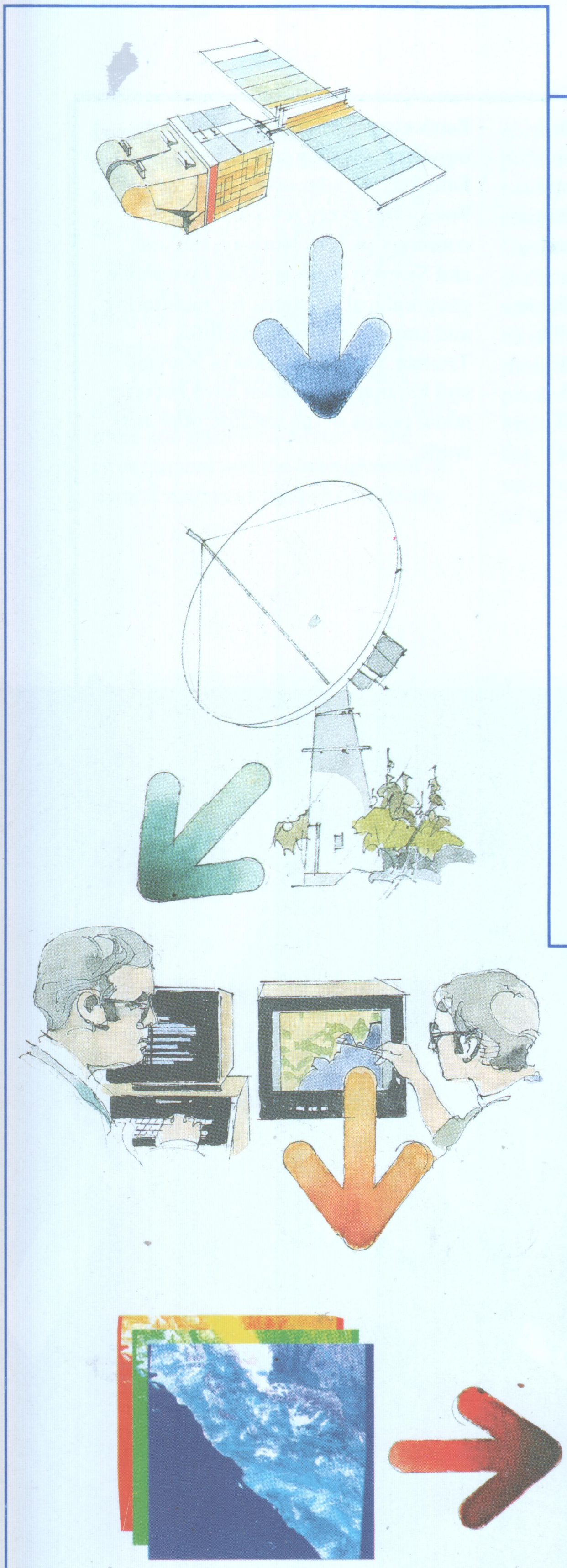
Earth observation satellites, on the other hand, move in lower, polar orbits, 600-800 kilometres above the ground. As the satellite moves in its orbit and as the Earth rotates on its axis, new data is recorded until full coverage of the Earth has been obtained. This is a continuous process and, therefore, both short- and long term changes can be registered and analysed.

The time required for a satellite to complete one revolution around the Earth varies depending on its orbit. For example, the SPOT and ERS-1 satellites take 100 minutes. SPOT passes over the same point on the Earth every 26th day and between transits covers the whole Earth. Satellites in polar orbits pass overthe Poles once every revolution. In countries such as Norway, Finland and Sweden there are thus favourable geographical locations for monitoring and controlling these satellites. Tromsø Satellite Station in Norway and Esrange in Sweden have become nodal points in the satellite orbit network.



An example illustrating satellite orbits.
A polar orbit.
A geostationary orbit.

How do Satellites capture Data?



The sun emits radiation at many different wavelengths. Not all of this radiation reaches the Earth. The radiation which penetrates the Earth's atmosphere includes parts of the ultra-violet band, visible light and radiation close to the infra-red spectral band which is invisible. Different objects on the ground react differently to this radiation. They have differing radiation characteristics, called spectral signatures, which show how the reflected radiation is spread within the different wave lengths.

Radiation is measured and registered by the different sensors onboard the Earth observation satellites and is transformed into image data. This data can be reprocessed in computers on the ground and combined with other data for a wide range of applications such as in geographical information systems.

The size of objects which can be registered varies from satellite to satellite. The Landsat and ERS-1 satellites can register objects down to a size of 30 metres and SPOT satellites down to 10 metres.

The Red Sea coast.

Remote Sensing and its Applications

In order to be able to formulate policies and guidelines for dealing with environmental questions at global, national, regional and local levels, more precise data is needed about the atmosphere, the oceans, the polar areas, tropical rain forests, highly urbanized areas, agricultural patterns, vegetation, and meteorological conditions. Much of this data can only be captured by means of satellites.

Earth observation satellites can capture data from the same areas at regular intervals and thus register changes. The data may concern desertification, clear-cutting of forests, deforestation because of tree death, the extent of the Polar ice caps, the transport and depositing of silt in rivers and along coasts, and ocean currents.

Remote sensing makes it possible to:

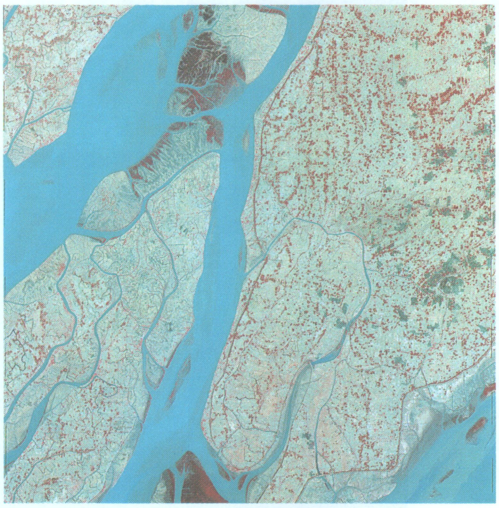
- measure the amount of ozone in the atmosphere
- analyse the interaction between the oceans and the atmosphere
- provide meteorological data
- investigate climatic factors
- map the Earth's resources
- carry out mineral prospecting
- map soil types and ground humidity
- follow up crop growth and fish harvests
- carry out inventories of forest resources
- study vegetation and measure the depth of the oceans and water quality

Examples of the use of remote sensing in the Nordic areas include the routine collection of data on waves and winds for nautical forecasting, and for the monitoring of ice and snow conditions.

Remote sensing is also an important tool for cartographic purposes, particularly in developing countries where there is often a lack of reliable maps.

The modern generation of Earth observation satellites such as SPOT have sensors which can be manipulated to record overlapping images which can be used to generate three-dimensional terrain models from which contours can be derived.

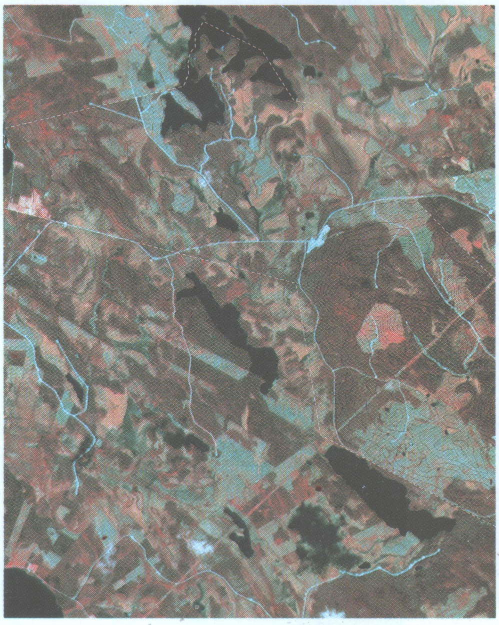
One example of the use of remote sensing with which we all come into daily contact via television, is weather forecasting, for which weather satellite data is used.



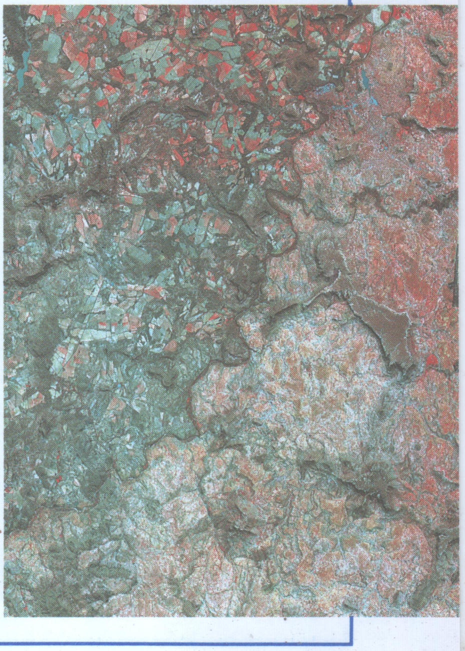
Satellite image map, Mapping, Bangladesh (SPOT).
©CNES/Satellitbild

Satellite image, Ice detection, Svalbard (ERS-1).
©ESA/TSS

Satellite image, Forestry applications, Västertjärn, Sweden (SPOT).
©Satellitbild



Satellite image, Environmental applications, Southern Africa (SPOT). *©CNES*

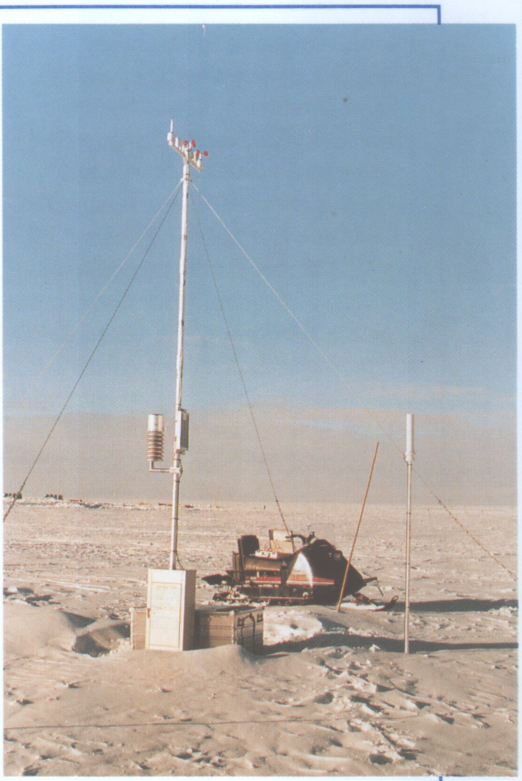


Denmark

Weather forecast and warning for storm floods

Ever since the first satellites were placed in orbit around the Earth during the 1960's, their role in the production of weather forecasts has steadily increased in importance.

The Danish Meteorological Institute (DMI) has satellite receiving stations in Denmark and Greenland. Weather satellites can be used for many purposes. They can be used to capture information in the form of imagery and meteorological measurements, and they contribute to weather monitoring by relaying data captured by special vessels in traffic in the Atlantic Ocean that release weather balloons (radio sondes). They are used to monitor sea ice around Greenland to ensure safe passage in those waters.



DMI's weather station on Greenland communicates via satellite.
Source: DMI

Storm flood warnings

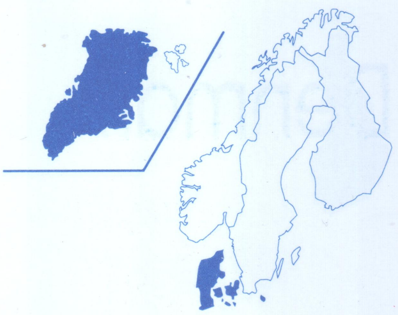
Storm floods along the west coast of Jutland can cause heavy damage and it is therefore vital to be able to prepare predictions for the occurrence of storm floods and high water in advance so that precautionary measures to minimize damage can be taken.

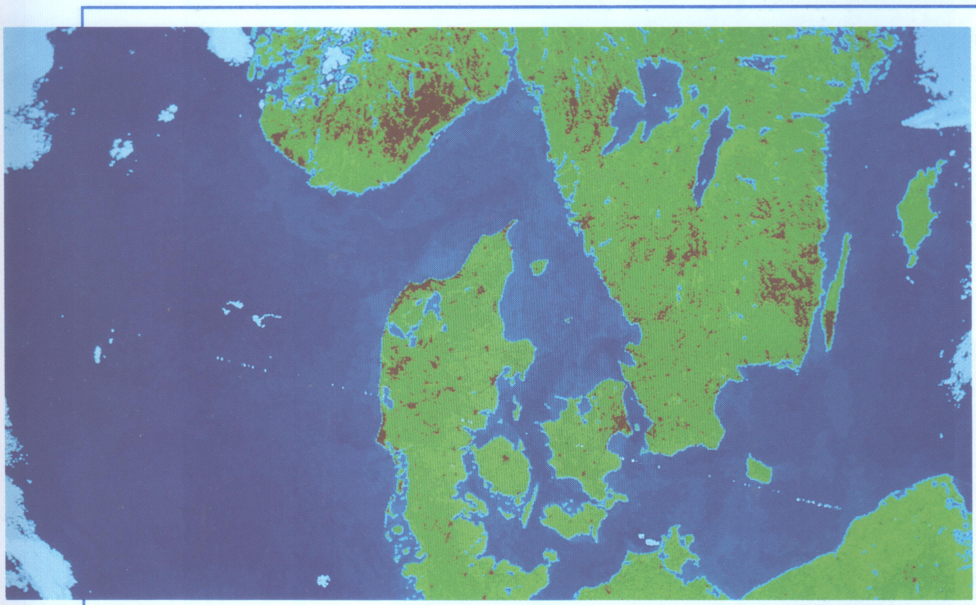
Reliable, detailed information about wind conditions is of critical importance for preparing storm flood warnings and satellites are valuable sources of such information.

Storm flood warnings have been issued by DMI since 1973. The first system, which was developed together with the Technical University of Denmark, was able to predict water levels three hours in advance. This was a major break-through.

Since then DMI has developed new warning systems with, amongst other organizations, the Danish Hydraulic Institute. The new systems are coupled to DMI's detailed weather model and it is now possible to prepare more reliable long-term forecasts. DMI is presently able to provide advance warnings up to 18 hours before an expected storm flood occurs.

Storm at Hirtshals.
©Svend Tougaard/Biofoto





A satellite image received at DMI and processed in the Institute's image processing system. In the image the coldest areas are clouds, which appears white. The warmer parts which appear red are urban areas and some sandy areas. Parts of the Limfjord and the Roskilde fjord cannot be distinguished from the nearby land areas because land and water have the same temperature. Across Denmark the remains of condensation from the exhausts of aircraft engines can be seen.
Source: DMI

During the storm of January 26th, 1990 the sea level rose to more than 4 metres above mean sea level in Vade Sea and the harbour at Esbjerg was flooded and severely damaged. A new system for storm flood warnings was developed during the following summer and was put into effect in the autumn of the same year. DMI can now warn the local population via radio and television 18 hours before the flood is expected.
©E.B. Schøidt

Predicting good crops or famine conditions

The Sahel area along the southern edge of the Sahara Desert is one of the most difficult areas on Earth for the production of the food needed for the survival of local population. The annual rainfall is only 300-400 mm but as it is concentrated to a period of 2-3 months it is possible to cultivate millet. However, the amount of rain is unreliable and during drought trees and plants wither. The scorched countryside is slowly being abandoned.

Observations of the Earth from satellites are used to monitor the most important resources such as vegetation and water. Satellites are thus a vital tool in the struggle against desertification.

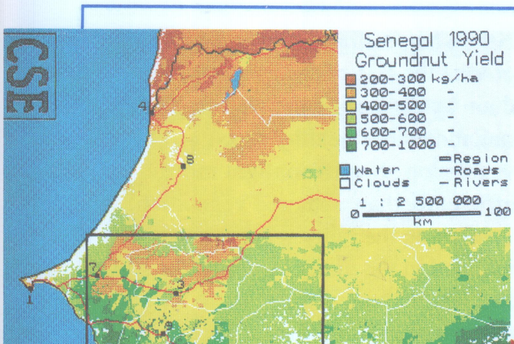
Data extracted from satellite imagery taken up to two months before harvesting can be used to predict the size of the harvest. This is done by measuring the reflected solar radiation since healthy green vegetation absorbs sunlight more efficiently than withered vegetation.

During the rainy season, water is retained in the upper layers of the soil, and where there is water there will be transpiration from plants. This process, which is also called evapotranspiration, uses energy in the form of heat. Therefore, in those areas where the surface is covered by growing, green vegetation the surface is relatively cool.

With the help of satellites it is possible to measure the temperature of the Earth's surface: low temperature values indicate humidity and higher values drought conditions.

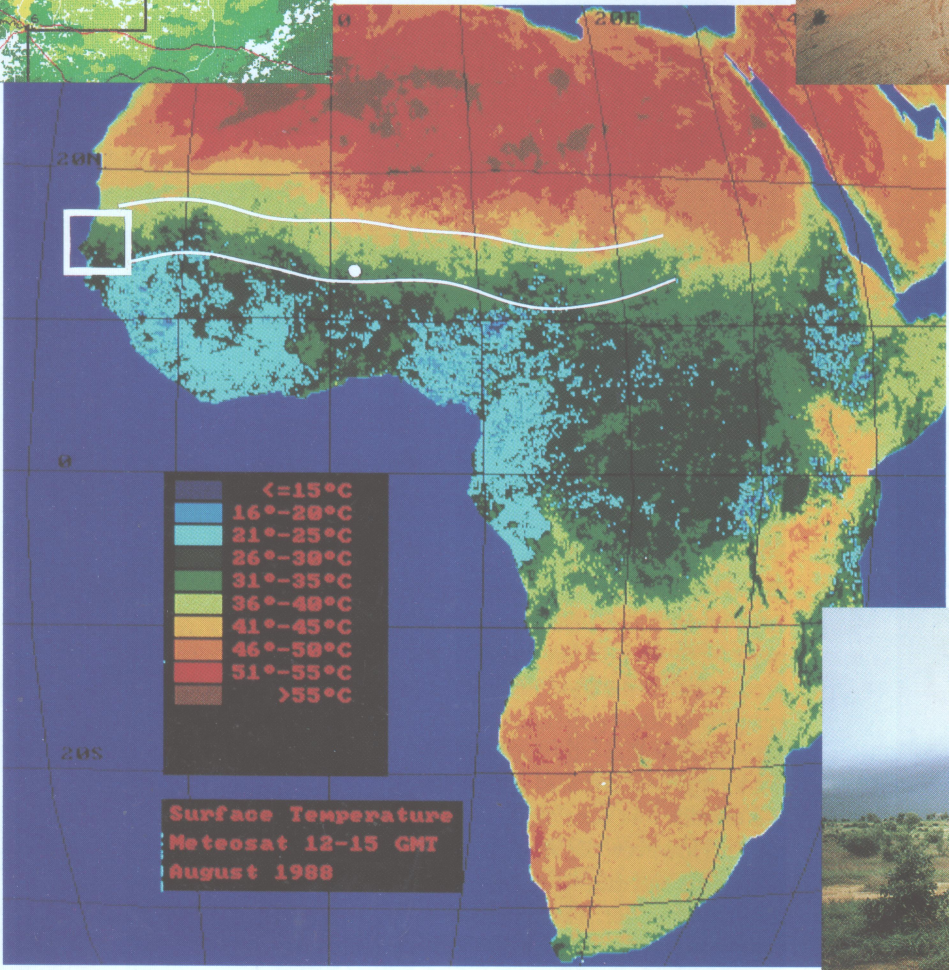
The millet harvest is carried home.
Source: Geograph. Inst., Univ. Copenhagen

Denmark



Measurements of reflected solar radiation for predicting the groundnut harvest in Senegal. ©NOAA/CSE: Centre de Suivi Ecologie, Dakar.

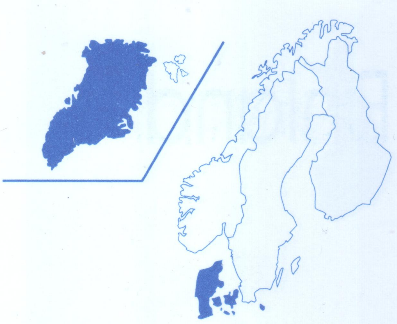
View from an intrumentation mast of an area in the process of desertification. Source: Geograph. Inst., Univ. Copenhagen



Surface temperatures in Africa during August 1988 recorded by Meteosat. The lines indicate the Sahel area. Source: Geograph. Inst., Univ. Copenhagen

The sky before rain. This cloud gave 50 mm of rain in the course of a few hours. Source: Geograph. Inst., Univ. Copenhagen

Researchers at the Geographical Institute at the University of Copenhagen are cooperating with institutions in the Sahel countries to develop methods to improve techniques for predicting crop yields and thereby reduce the risk of famine.



Satellites and mineral prospecting in Greenland

In Greenland, satellites are used for several purposes including monitoring ice and prospecting for minerals.

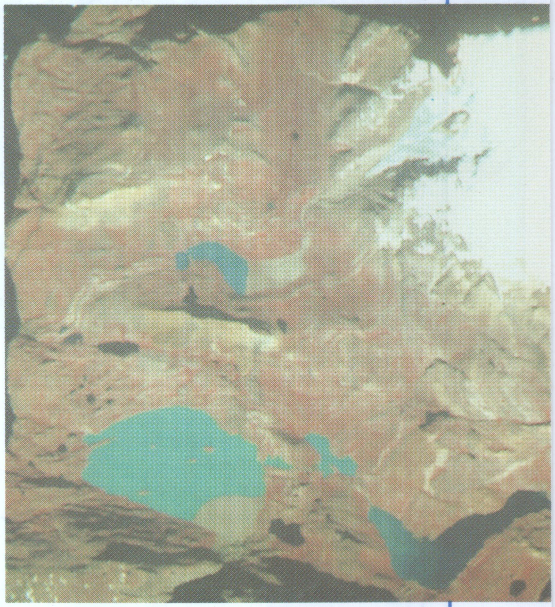
Satellite imagery (upper right) is used for prospecting in the central parts of eastern Greenland, where geologists are trying to find deposits of scheelite which contains wolfram.

The image was made by the American Landsat satellite and consists of 512x512 pixels each of which is equivalent to 30x30 metres on the ground. Every pixel has seven numerical values, each of which represents a light intensity value for visible and invisible light.

The image is thus built up from a large number of values which can be mathematically and statistically analysed.

The section covers an area of 15x15 km. The white area in the upper right part of the image is glaciers and the turquoise and dark-coloured areas are sea and lakes. At the southern edge of the large lake the grey area represents deposits from the outflow of a river. The red-brown area shows various terrain formations such as moraine and various rock types.

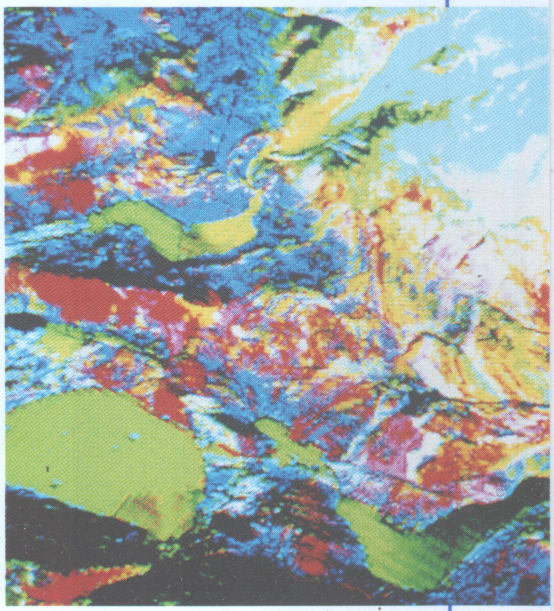
Using knowledge of the geology of the area it is possible to process the image statistically in a computer so that the geological units will be more prominent. The result can be seen in the picture (bottom right) in which the colour and contrast differences have been enhanced in comparison with the picture above. Geological ground truth combined with images taken from a height of 800 kilometres have thus been used to create a better basis for prospecting in the area.



Satellite image of the island of Ymer in Eastern Greenland. **Source: IMSOR**

A photography of Mount Rosinante which can be seen between the two lakes in the middle of the satellite image. **Source: IMSOR (Technical Univ. of Denmark)**

A processed satellite image of the island of Ymer. **Source: IMSOR**



Finland

The use of satellite imagery for land-use and vegetation inventories

Land-use and vegetation are continually changing. These are two elements which affect many areas of society and the environment, such as water resources, rural and urban planning, environmental care, and the forestry industry. It is therefore important to have rapid access to information about any changes that take place. Space-based remote sensing is highly suitable for such inventories. It is easy to produce maps of large areas, and in addition to get new imagery of the same area annually.

In Finland, the development of techniques for the use of satellite imagery (Landsat and SPOT) for inventories of land-use and vegetation began in 1975. The goal is to establish a database containing data captured from inventories repeated every four years, which can be used to reveal and monitor changes.

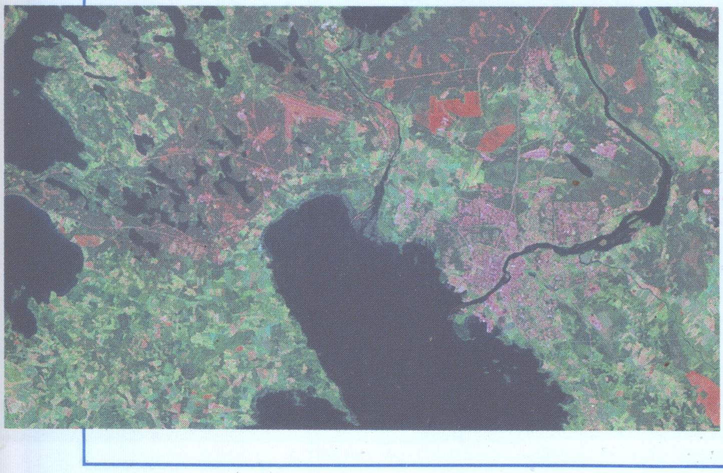
The methodology for the inventory is based on the numerical interpretation of satellite imagery used together with digital map data, and was developed some years ago. The first inventory in Finland was completed at the beginning of 1991 by the National Board of Survey (NBS). The results have been presented in the form of a thematic map in a digital raster format in the same grid system as is used for the Finnish national topographic map series. This means that it is possible to combine information with other spatially related data.

In the classification the main classes are water, arable land, forest clear-cuts, forest land with standing crop, thicket type forest, bogs and marshland. It is possible to make a more refined inventory and break down these classes to include different forest types and categories of use.

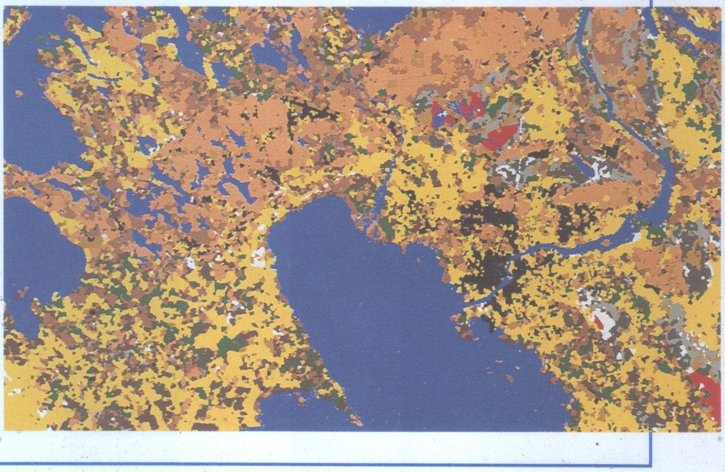
Land-use classes

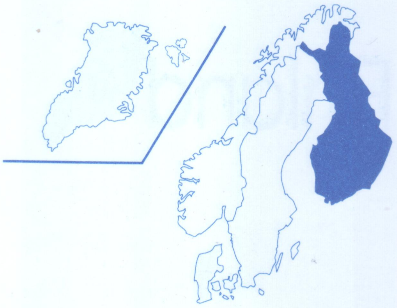
- 🟦 River/stream
- 🟫 Clear-cuts
- Open bogs
- 🟥 Peat production
- ⬜ Forest marsh
- ⬛ Bogs
- 🟨 Arable land
- ⬛ Open area
- 🟧 Pine forest
- 🟫 Spruce forest
- 🟩 Deciduous forest
- 🟫 Mixed forest
- ⬛ Thicket type forest

Corrected image recorded by Landsat.
Processing: NBS



Land-use classes interpreted from the Landsat-image.
Processing: NBS



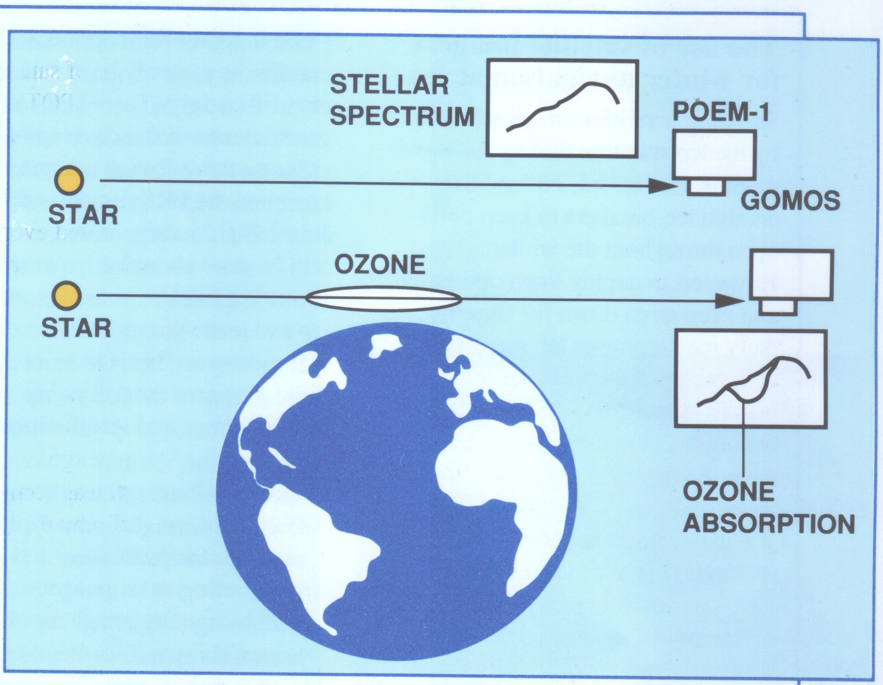


Atmospheric studies

Using land-based observations alone it is possible neither to obtain a sufficiently large sampling of the atmosphere nor to follow up changes. Satellites in a polar orbit offer a good platform for measuring of atmospheric characteristics. The most acute problem in t[illegible]ntext of atmospheric change[illegible]at the amount of ozone in the stratosphere is decreasing.

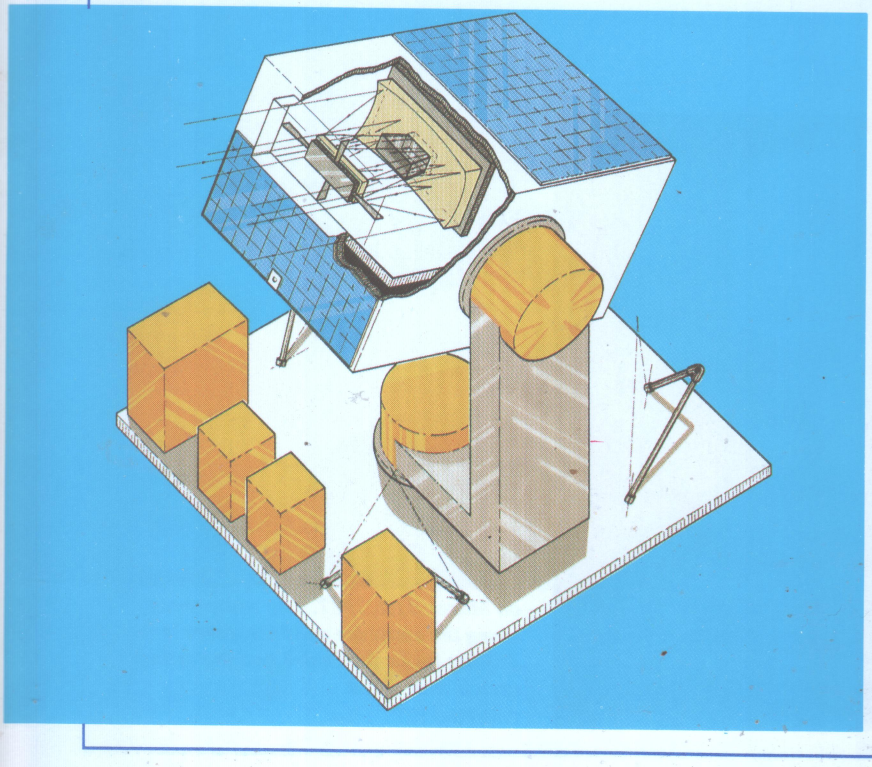
New satellites launched at the end of the 1990's will be equipped [illegible] improved instruments for measuring the ozone content of the stratosphere. This will enhance our ability to monitor changes in the atmosphere.

Together with a number of other European coun[illegible]nd has develo[illegible]er – GOMOS – for space-based monitoring of the amount of ozone in the stratosphere. This spectrometer will be used by ESA in one of its polar orbiting satellites which will be launched towards the end of this decade. Approximately four hundred observations per day will be made with GOMOS. It ought to be possible to measure annual changes of about 0.05% in the volume of stratospheric ozone.



The instrument GOMOS measures the composition of the atmosphere by using the occultation of stars. The spectrum of the star is measured 40 times during one occultation. The spectrum is also measured when the star is visible above the atmosphere. Changes in the spectrum are used to compute the distribution of ozone in the atmosphere.

Source: Finnish Meteorological Institute



Construction features of the GOMOS spectrometer.

©Matra Espace

Finland

The use of satellite imagery for winter navigation at sea

Shipping activities are greatly affected by the ice situation during the winter months. At present, Finland has enough ice-breakers to keep ports open throughout the winter. However, to deploy them optimally and keep costs down for shipping, daily ice prognoses are required.

Remote sensing technology is a powerful tool for monitoring ice conditions at sea since imagery covering large areas can be obtained daily.

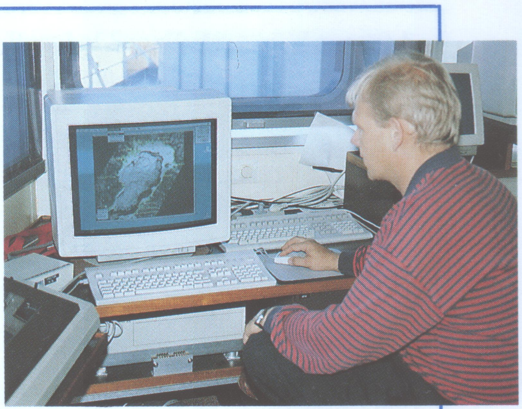
The development of satellite-based methods for the production of daily ice maps and ice situation reports, and for transmitting imagery to ice-breakers in real time, began in 1980. At the Meteorological Institute, imagery from weather satellites is received and it is then processed in the computers at the Marine Research Institute in order to improve its quality to make interpretation easier. The images are then sent via NMT (radio telephone network) to the ice-breakers. The results have been good.

Good imagery for mapping ice conditions can only be obtained on cloud-free days. There is therefore great interest in the developing of radar methods for ice mapping. ESA launched the ERS-1 radar satellite in July 1991. Imagery from this satellite will be used aboard ships at sea to identify ice ridges, solid ice, drifting ice and leads through the ice.

If radar imagery is to be used for these purposes the following developments and installations will be needed:

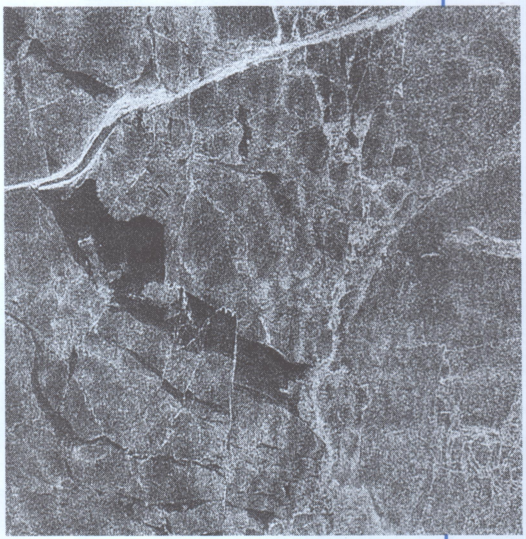
- models for interpreting radar reflections from different types of ice
- methods for processing and interpreting radar imagery
- a high-capacity image monitor for use on ships and ice-breakers

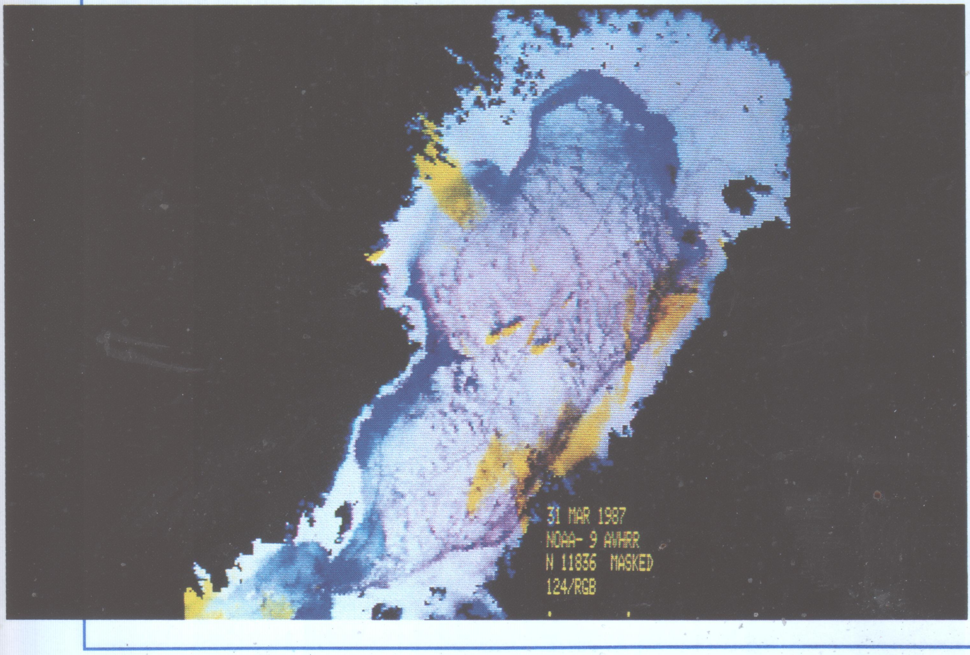
The first demonstration projects using ERS-1 data will be carried out during 1992 when the radar imagery will be used to assist winter navigation in the Gulf of Bothnia. Towards the end of this decade, when there is a sufficient number of radar satellites in orbit, the imagery will be used to prepare daily ice prognoses.



Checking the ice situation in the Gulf of Bothnia. The image monitor on the ice-breaker Kontio.

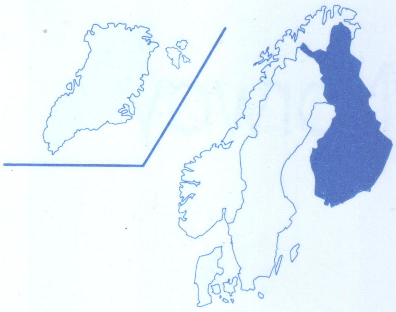
A radar image of the Gulf of Bothnia. The structure of the ice and the leads (the light coloured area) can be clearly identified.





The ice situation in the Gulf of Bothnia on March 31st, 1987. The white areas along the coast are solid ice, there is drifting ice in the centre and the yellow area is thin cloud.

Processing: VTT



The determination of snow volumes using satellite imagery

The period during which snow falls and the amounts which fall vary from year to year and the volumes can have daily and weekly variations. These are factors which have a significant effect on energy production, water resources, traffic etc., in Scandinavia. It is vital to have information about snow volumes and variations in the volumes throughout the region, in both rural and urban areas, to be able to study the effects of snow on the environment and on trade and industrial activities.

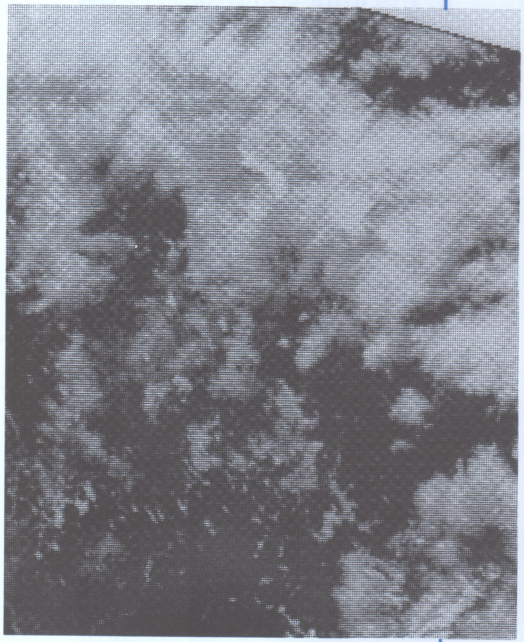
Such information can be gathered for large areas by means of satellites. Interest focusses on measuring two of the most important characteristics: the extent of the snow cover and its water content. To carry out these measurements throughout the whole snow period optical and microwave instruments are used.

Towards the end of the 1970's methods for measuring snow volumes with radiometers began to be developed. These instruments record microwave radiation from snow and by using a multi-frequency system it is possible to determine water content. This technology can also be used to determine the extent of the snow cover. The method is most effective during the winter when the snow is driest.

During the spring optical instruments are more suitable for measuring the snow cover and following up melting. The water content of the snow cover can also be measured by registering radiation from partly melted snow cover areas. Knowledge of snow volumes is necessary for the preparation of hydrological prognoses.

In the near future research will be carried out on how ERS-1 radar data can be used to measure the water content in snow and identify areas where snow is melting. Results of this research will be available in a few years time.

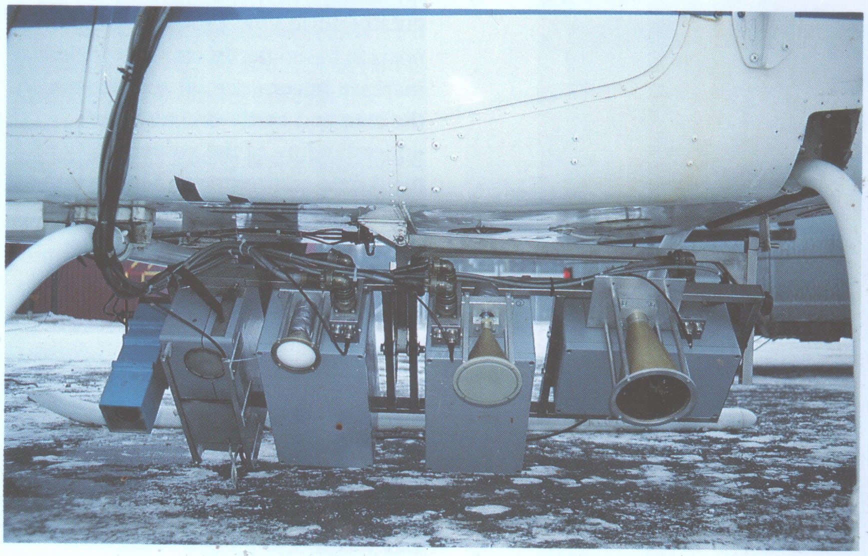
Snow in Sodankylä at the beginning of May.



The snow situation in northern Finland on May 9th, 1983. Image recorded by a NOAA weather satellite. The dark areas are snow-free.

Processing: VTT

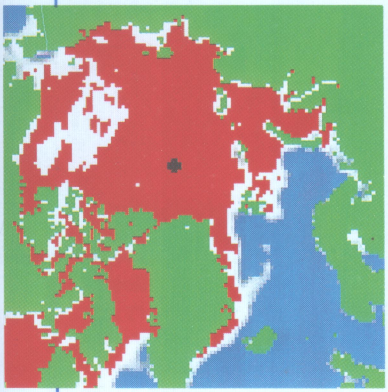
A microwave radiometer mounted in a helicopter. This equipment, which operates on frequencies between 24 GHz and 94 GHz, is used for remote sensing of snow (the Space Technology Laboratory of the Helsinki University of Technology).



Norway

Efficient monitoring of ice conditions brings safer working conditions to the Barents Sea

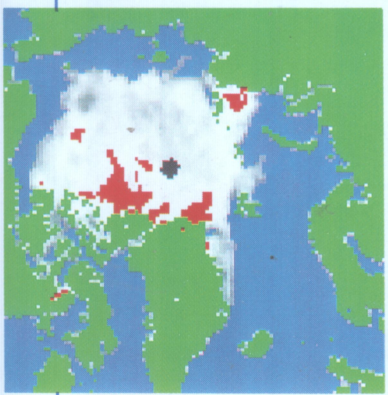
The Barents Sea covers an ocean surface of 1.4 million square kilometres, of which the greater part lies within the Russian and Norwegian Economic Zones. Within the area there probably are gas and oilfields and the fishing reserves are amongst the most important in Europe. Exploitation of these resources is severely restricted by ice and icebergs. During the winter months as much as 70% of the area can be covered by ice 1-3 metres thick, while during the summer only the northernmost 20% is covered.



The extent of the ice in the sea surrounding the North Pole on February 18th, 1989. SMMI.

Processing: NERSC

Red: more than 90% ice cover
Grey: 10 - 90% ice cover
Blue: less than 10% ice cover
Green: land
Black: no data available



The extent of the ice in the sea surrounding the North Pole on September 10th, 1989. SMMI.

Processing: NERSC

The Norwegian fishing fleet would like to have very detailed daily information about the prevailing ice conditions. Offshore industries and other maritime groups working in the Barents Sea also require detailed up-to-date information.

At present ice warning services in the Barents Sea are restricted considerably by generally cloudy conditions which prevent data acquisition by satellites equipped with optical sensors.

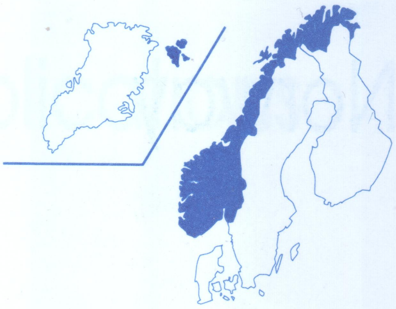
In order to meet the needs of users, the Norwegian government has established a unit for ocean monitoring, HOV, which is responsible for all ocean monitoring including information about ice conditions. The task of HOV is to provide clients, on request, and on a daily basis, with ice maps based on measurements with passive microwave data from SSMI, ice-warning maps and selected imagery from ERS-1.

The need for daily monitoring of ice conditions is expected to increase greatly during the 1990's. This prognosis is based partly on an expected increase in commercial activities in the area and partly on increased understanding of the vulnerability of the Arctic environment. More extensive tourism, the associated need for improved rescue services, and the possibility of opening the North-East Passage to Japan and the Far East for ordinary shipping are other reasons.

Demonstrating how direct monitoring of ice conditions can be carried out with the help of satellites is an International Space Year project for ESA. The primary source of data will be SAR imagery from the ERS-1 satellite, but data from NOAA AVHRR and DMSP SSMI will provide vital supplementary information.

When operational services have been developed a daily procedure could be as follows: a client requests information about ice conditions in an area of the Barents Sea. Radar data is received from a suitable radar satellite and processed in real time at Tromsø Satellite Station. The images are further processed by a commercial organization and the information is supplemented by additional data from satellites with optical sensors, passive microwave sensors and land-based observations. The final maps are sent to the client, at the latest, within four hours of obtaining the satellite recordings.

The edge of the ice in the Greenland Sea. ERS-1 SAR image. January 8th, 1992.
©ESA/TSS

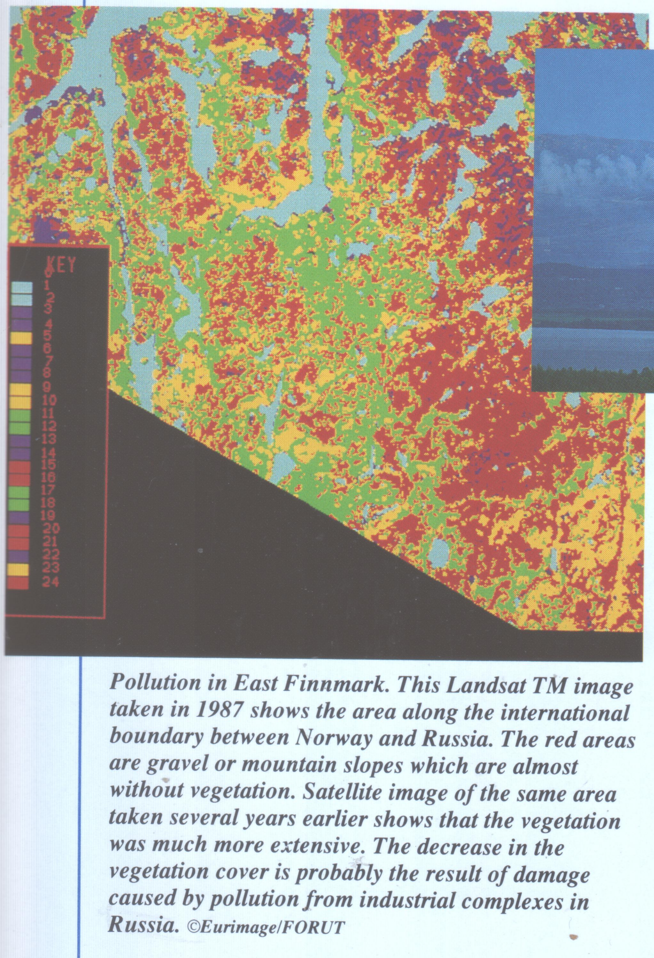


Pollution without limits

In Sør-Varanger in Finnmark a noticeable change in the vegetation has been registered during the last few years. The lichen cover which is very sensitive to air pollution has decreased drastically. Experts agree that the reason for this is pollution from the large nickel refining complexes in the Russian cities of Nikel and Zapolyarny.

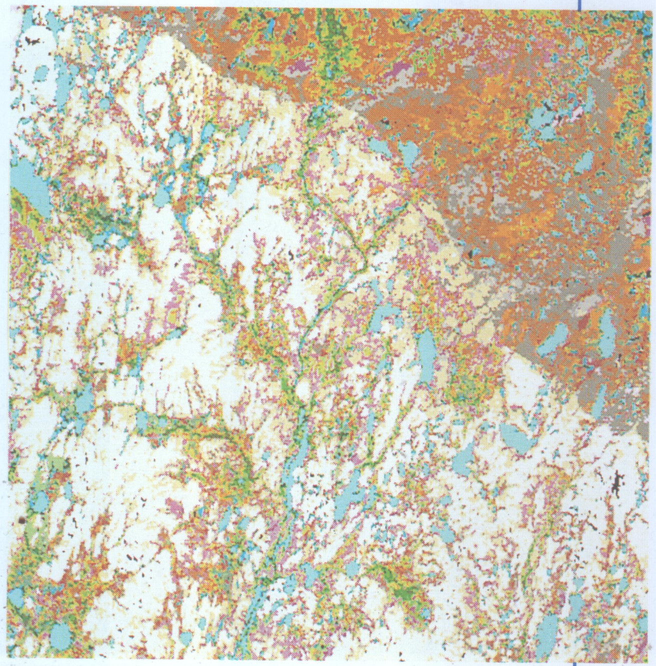
A comprehensive inventory of the damage in the area has started. Maps based on satellite data is being produced to show the types of vegetation which have previously existed in the area and those that are left. Data has been collected from 1973, 1985 and 1988. In conjunction with field analyses and measurement of heavy metals in lichen, moss and crowberries the maps provide sufficient information for registering and, it is hoped, for making decisions that will help reduce the damage to which the natural environment is being exposed.

The maps are based on Landsat data. The results show that it is possible, with the help of pollution maps based on satellite data, to distinguish four main zones which have suffered significant damage as a result of pollution. In the areas around Nikel and Zapolyarny the forest, mountain and grass vegetation types at higher altitudes are severely damaged or dead. In the next zone, the lichen cover has disappeared in higher terrain where even the greater part of the birch forest is badly damaged. Severe burn damage has been found on heather. In the third zone, burn damage to young pine trees has been found together with damage to aspens. The vegetation in the zone furthest from the smelters is relatively unaffected.



©Jan Arve Dale/Samfoto

Pollution in East Finnmark. This Landsat TM image taken in 1987 shows the area along the international boundary between Norway and Russia. The red areas are gravel or mountain slopes which are almost without vegetation. Satellite image of the same area taken several years earlier shows that the vegetation was much more extensive. The decrease in the vegetation cover is probably the result of damage caused by pollution from industrial complexes in Russia. ©Eurimage/FORUT



The image (Landsat TM) shows the area along the international boundary between Norway and Finland. Vegetation used to cover almost equal areas on both sides of the boundary (which is a fence built of stone and wood). The white areas are reindeer lichen. The brown areas are gravel or montain slopes almost without vegetation. Over-grazing on the Finnish side of the boundary has resulted in in the disappearance of reindeer lichen. Further north on the Finnmarksvidda, in Norway, the situation is similar. ©Eurimage/FORUT

Norway

Monitoring shipping

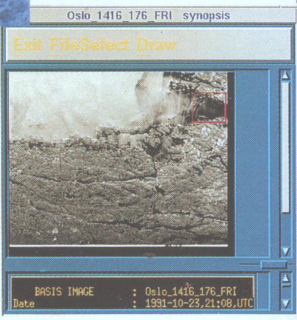
Norway's Economic Zone covers more than two million square kilometres. The Norwegian Coastguard which has the responsibility for the continuous monitoring of this area has a very difficult task with the means at its disposal. Monitoring is done mainly from aircraft, large vessels with helicopters or from smaller vessels. There can be as many as a thousand vessels at sea in the Norwegian zone at the same time, fishing, engaged in other commercial activities, or just passing through the zone. Normally the Coastguard carries out 2,500 inspections per year.

Monitoring involves a chain of activities: early detection, determination of position, classification, identification and inspection, and human presence is absolutely vital. Satellites could be a useful supplement to traditional methods, particularly in the first link of the chain, because of their ability to cover wide areas in a short period of time. The ability of radar satellites to observe phenomena on the surface of the sea, irrespective of light conditions and cloud cover, should be of particular value.

At the Norwegian Defence Research Establishment, development of methods for automatically monitoring shipping with the help of radar imagery analysis has been in progress since 1986. The methodology is based on analyses of 200 radar images from the American radar satellite SEASAT which was operational for three months in 1987.

Experience with imagery from the ERS-1 satellite indicates that with more radar satellites in orbit at the same time it would be possible to monitor the Norwegian Economical Zone automatically, fix the position of ships, determine speeds, direction and size. ERS-1 on its own can be of great value in the areas around Svalbard. The satellite covers these northerly areas well and can, for example, monitor those vessels which are fishing inside a given zone.

© Helge Sunde/Samfoto



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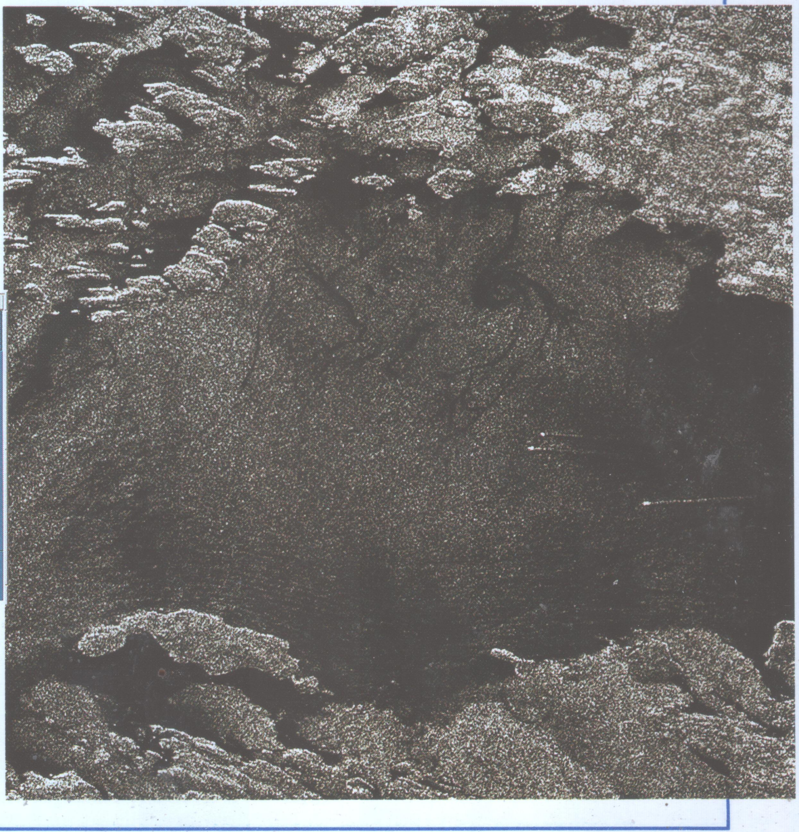
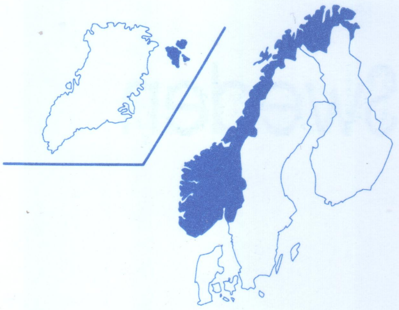


An ERS-1 SAR image, recorded on October 23rd, 1991, showing the Oslo Fjord near Tønsberg. Three ships and their wakes and a small eddy closer to the shore can be identified in this ERS-1 SAR image. North is to the right of the image.

©ESA/TSS/Spacetec



Satellites for mapping vegetation cheaply and efficiently

By using satellites instead of aircraft vegetation maps can be produced more easily and quickly and at lower cost. The cost of producing 720 map sheets using traditional methods would be NOK 240,000,000 and take 240 years. With satellite imagery the same task would take five years at a cost of NOK 50,000,000.

Vegetation maps produced from satellite imagery can be used for a wide range of activities, for example:

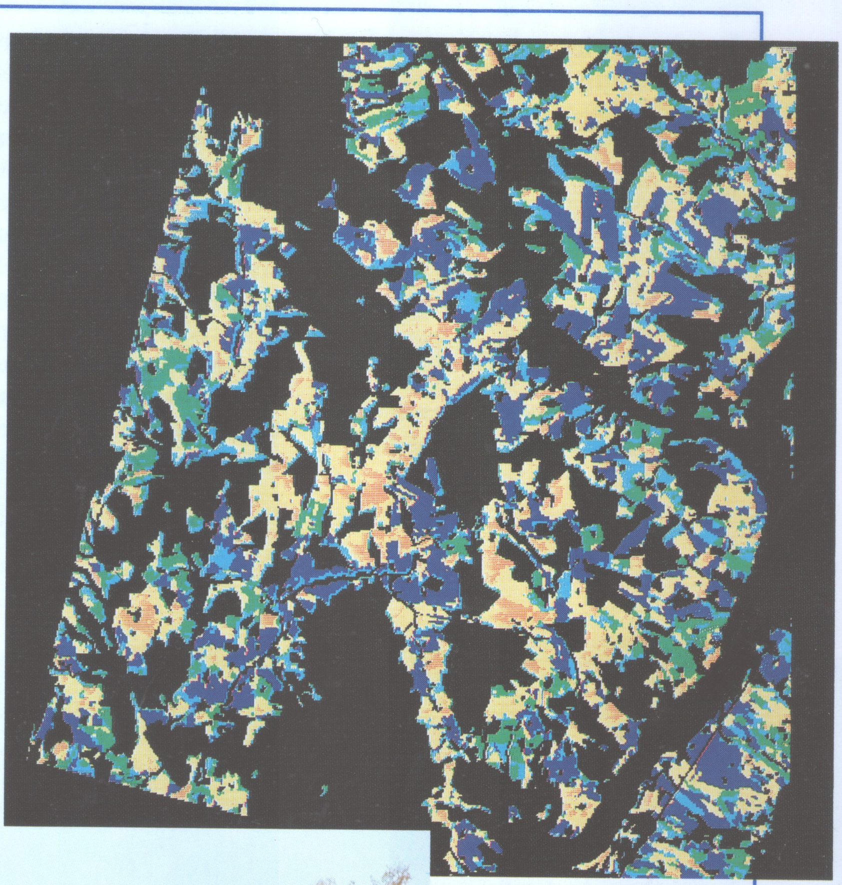
The city of Tromsø needed a map of its surroundings for developing transport infrastructure. In addition, the map will be used as the basis for the strategic planning of open and recreation areas.

The Norwegian Defence wanted to evaluate damage to vegetation in training grounds in Bardu and Målselv. Vegetation mapping was carried out as the basis for the planning of exercises in this area.

On Svalbard, a general map was produced showing vegetation groups and important ecological/climatic factors which are of decisive importance for the evolution of Arctic types of vegetation.

Reindeer owners in Finnmark needed a general picture of the availability of lichen grazing in the area. The lichen areas were classified on basis of the amount of grazing, and the maps therefore constitute an important basis for reducing of the number of reindeer in the plains of Finnmark. Reduction will be based on the information in the maps. The use of satellite data, image processing and analysis and field work produce favourable results in terms of both economics and timesavings.

The discharge of nutrient salts as a result of human activities will be reduced. An important source of these salts is agriculture, in particular the run-off from arable land which has been worked in the autumn. The authorities suggest restricting autumn ploughing in areas which are sensitive to erosion. To test whether voluntary measures will help, the State Pollution Control Authority will monitor farming activities in areas along the North Sea coast. Good results have been obtained from test mapping done using data from Landsat and SPOT satellites. The first results using SAR imagery from ERS-1 are also positive.



The image shows autumn ploughing (blue colour) in an area subject to severe erosion. Ploughing should not be done in the autumn. Landsat TM.

©Norwegian Computing Centre

©Husmo-foto

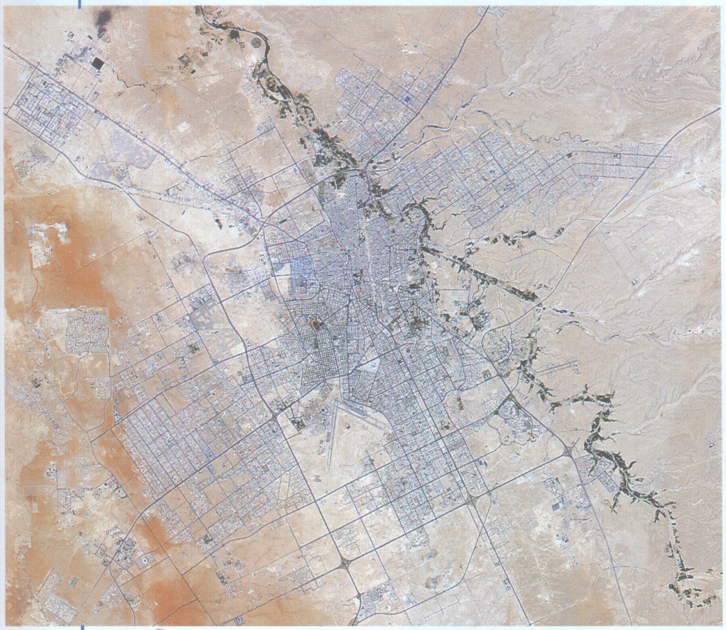
Images from space - an outstanding tool for mankind

Swedish competence in the field of Earth observation is well advanced, judged by international standards. There are four main factors which have been fundamental to the development of this competence.

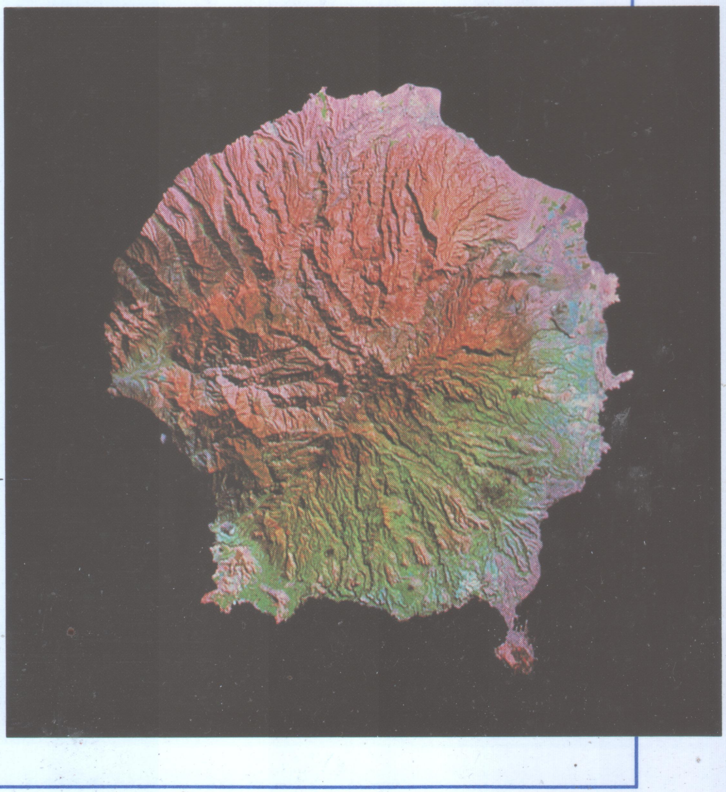
The first has a historical background. Mapping in Sweden has deep roots and questions related to the environment and the management of natural resources have, by tradition, occupied a central position on the political stage. The first systematic, national mapping of Sweden was started in 1628 on the orders of King Gustav II Adolf. In the 1930's production of a national land-use map series based on a controlled photo mosaic was begun; and in 1967 the mosaics were replaced by orthophotos. Since 1972, when the first high-resolution Earth resources satellite, Landsat 1, was launched, remote sensing technology based on the use of satellites has been utilized to rapidly gather information about land use and to register changes in the landscape.

The second factor is that, relative to its population, Sweden is rich in natural resources: half of the country is covered by forests and there are approximately 100,000 lakes.

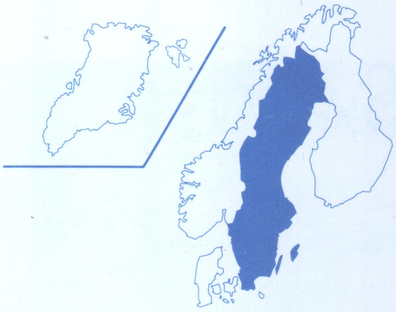
The third is related to technology. Sweden has a well-founded reputation as a high-technology country. This is particularly the case in the computer sector where many interesting applications have been developed by Swedish scientists. The last but not least important factor is political: through the years, successive Swedish governments have encouraged the use of data from satellites and remote sensing technology.



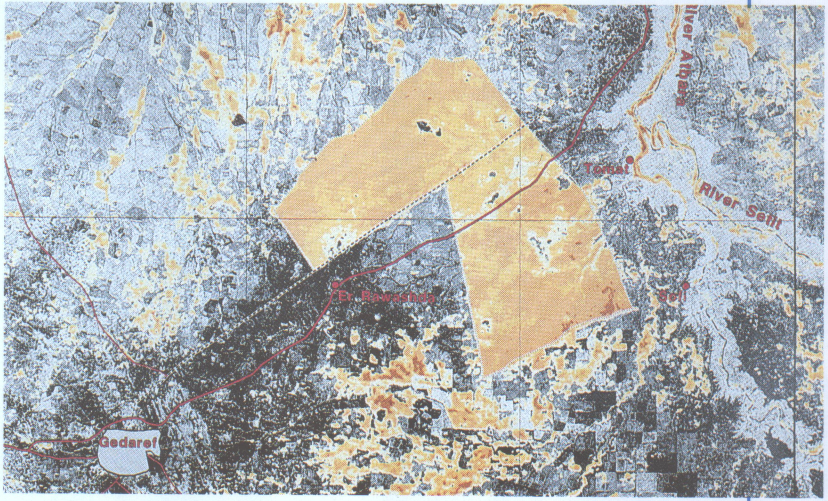
Riyadh, Saudia Arabia. Built-up areas are shown in blue.
©CNES/Satellitbild



Gran Canaria seen from a height of 700 km.
©Eurimage/ESA



International Environmental Projects



Part of a woody biomass map of a forestry reserve close to Rawashda in eastern Sudan. The yellow and brown areas on the map represent different amounts of forest cover expressed in percent.

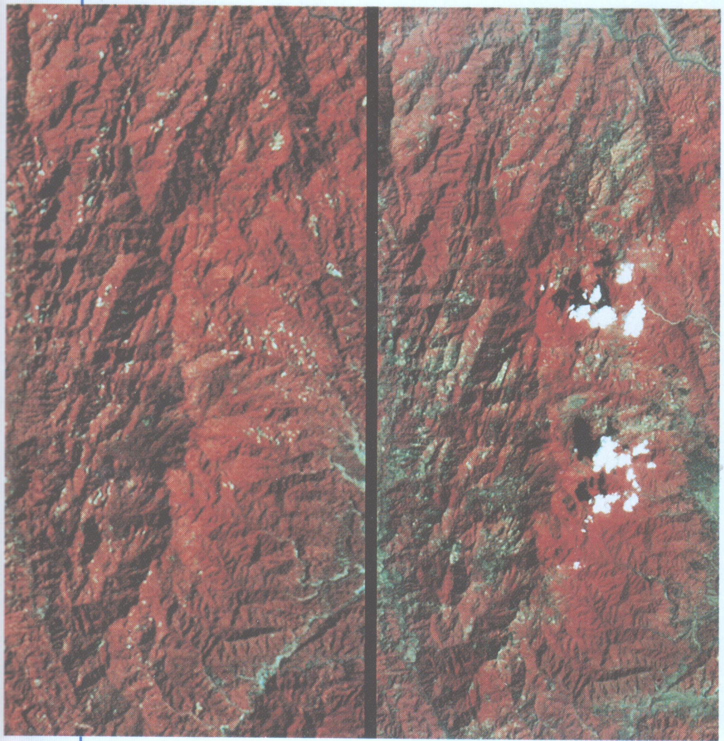
The use of remote sensing technology for data capture has a great potential in developing countries, which often lack reliable information about their natural resource, the state of the infrastructure and the condition of the environment. In many countries there also is a lack of up-to-date maps. For these countries satellite-based Earth observation would seem to be a necessity if material for the formulation of national development plans is to be made available within the foreseeable future.

A number of projects which are being carried out by Swedish remote sensing specialists are described below.

At the Department of Physical Geography of the University of Lund there is a number of environmental projects in which remote sensing methodology is being used. One such project is a study of energy resources in the Sudan. On behalf of FAO – the Food and Agriculture Organization – the Institute, together with a local consulting company, Lund Team AB, has carried out a comprehensive inventory of woody biomass, which is by far the most important energy raw material. An area about 50% larger than Sweden has been mapped at a scale of 1:250,000. The mapping has been based on 25 Landsat images from which forestry information has been extracted by means of manual image interpretation, field work and computerized, digital image analysis. By using a colour plotter, maps have been produced showing the volume of woody biomass in tons per hectar.

In Chiang Rai Province in northern Thailand a study of changes and estimates of the deforestation rate in areas of tropical forest has been carried out using Landsat MSS and TM imagery. The project was carried out jointly by the Swedish Space Corporation, the Swedish University of Agricultural Sciences in Umeå, FAO and the Royal Forestry Department in Bangkok.

The image (MSS) on the far left shows in red the forest cover as it was in 1977. The image (TM) on the right shows the situation in 1990.

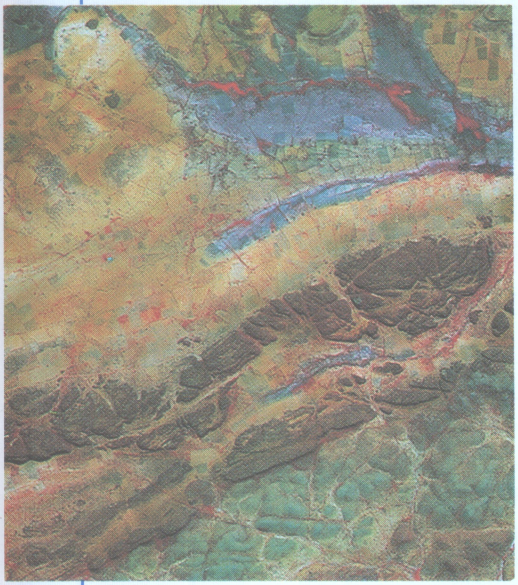


Chiang Rai, Thailand
©SSC

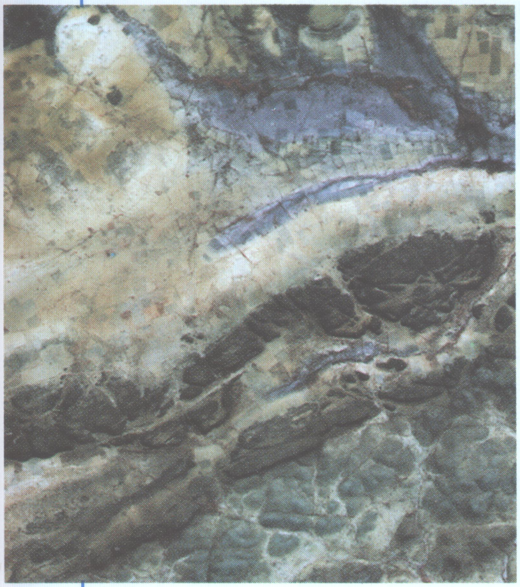
Sweden

In Central Botswana the Swedish Space Corporation and the consulting engineering company VIAK AB have carried out a project to improve the quality of imagery so that it can be used to locate supplies of subsurface water. In this project both SPOT and Landsat TM imagery were used.

The SPOT XS images below show the area during the dry season (May 30th, 1986) using standard colour coding, (upper left), and after manipulation and stretching to improve quality (bottom left).



Botswana
©SSC



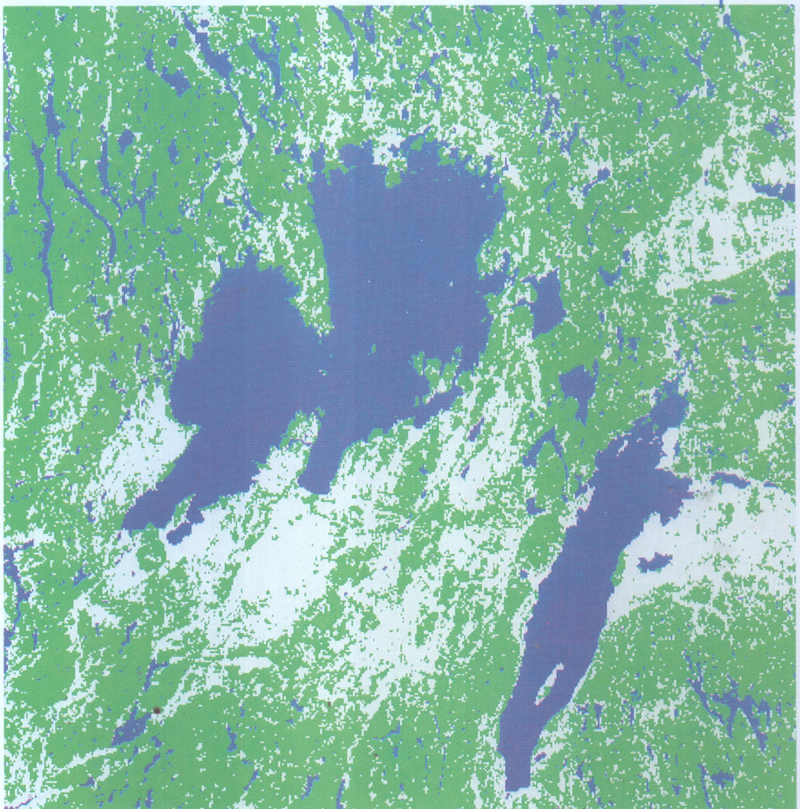
Swedish Environmental Studies

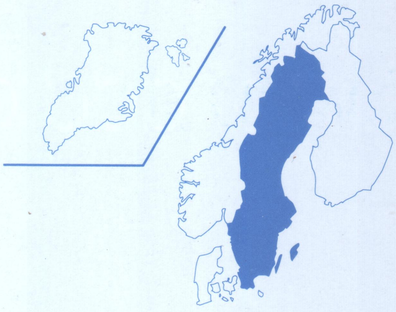
In a country such as Sweden, with its long tradition of mapping and where the natural resource base is well known, the role of remote sensing differs from, but is no less important than in other less well-mapped countries. In addition to its use for environmental monitoring and protection it is a valuable tool for the optimum planning and exploitation of forest resources.

Using a nationwide digital classification of vegetation which was developed using Landsat TM data, The Swedish Space Corporation is carrying out a project to produce a general map showing the distribution of forest areas in Sweden. The image on the right shows the area around the two lakes Vänern and Vättern.

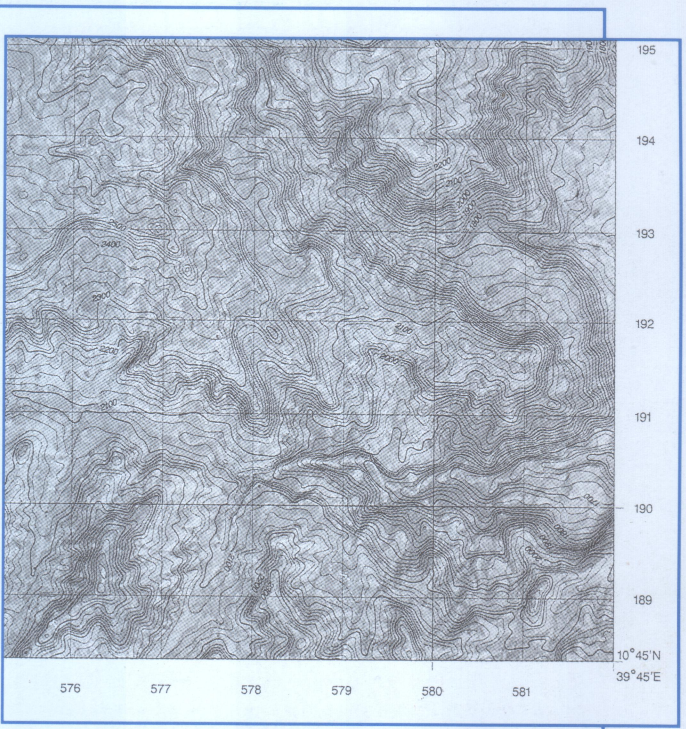
A project is being carried out by the Swedish Environmental Research Institute to make an inventory of the blooming of algae along the coasts of Sweden. Landsat TM is the data source which is being used. By measuring colour changes, which are correlated with the amount of chlorophyll a, it is possible to determine the amount of algae in surface waters. Algae contain chlorophyll and the amount of algae determines the amount of chlorophyll.

The distribution of forest in the area around the lakes Vättern and Vänern. © SSC

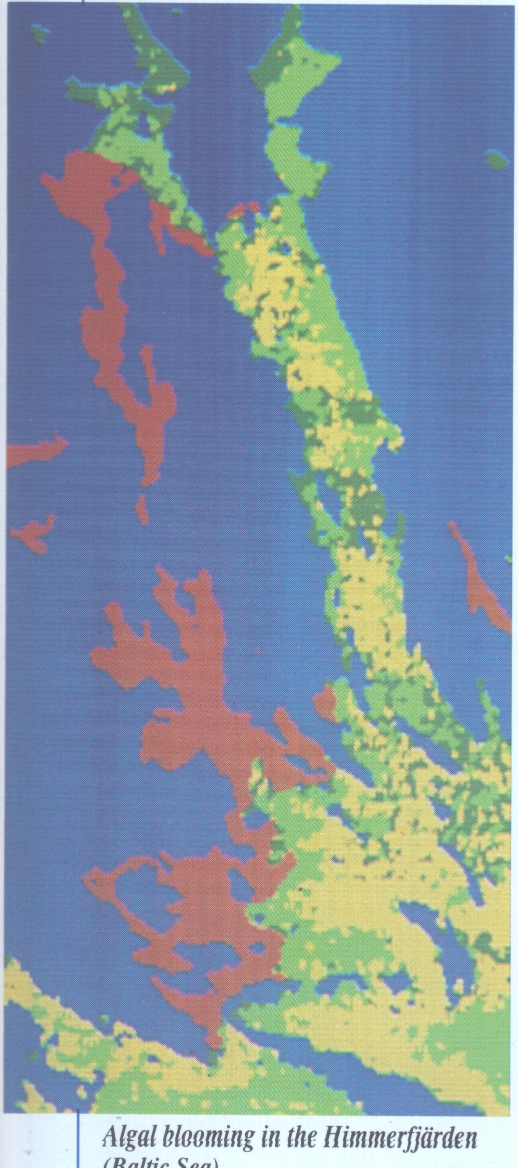




Normally, the blooming of diatomaceous algae in the spring will give rise to about 20-30 microgrammes of chlorophyll per litre. Using Landsat TM it has proved possible to reveal amounts of 5-10 microgrammes per litre. The illustration shows the amounts of chlorophyll a in the Himmerfjärden south of Stockholm.



A digital terrain model. The Dese area of Ethiopia.
©CNES



Algal blooming in the Himmerfjärden (Baltic Sea).

The colours have the following meaning: blue means 0-5 microgrammes per litre, green means 5-10 microgrammes per litre, red means area with a large amount of suspended sediment

New Techniques

At Satellitbild in Kiruna, digital terrain models are produced using SPOT stereoscopic imagery. The illustration at the right is an example showing the Desi area in Ethiopia, which lies approximately 100 kilometres north of the capital Addis Ababa. The image was made on 21st October 1990.

Contours with a vertical interval of 20 m were produced using a SPOT stereoscopic pair. The image background is an orthophoto – a geometrically corrected image – which has been made by correcting for the displacements in height which are the result of the oblique angle of the recordings.

ERS 1, the European Remote Sensing Satellite, is one of the most interesting of a new generation of remote sensing satellites. It is the first of a new type of satellites - the radar satellites.

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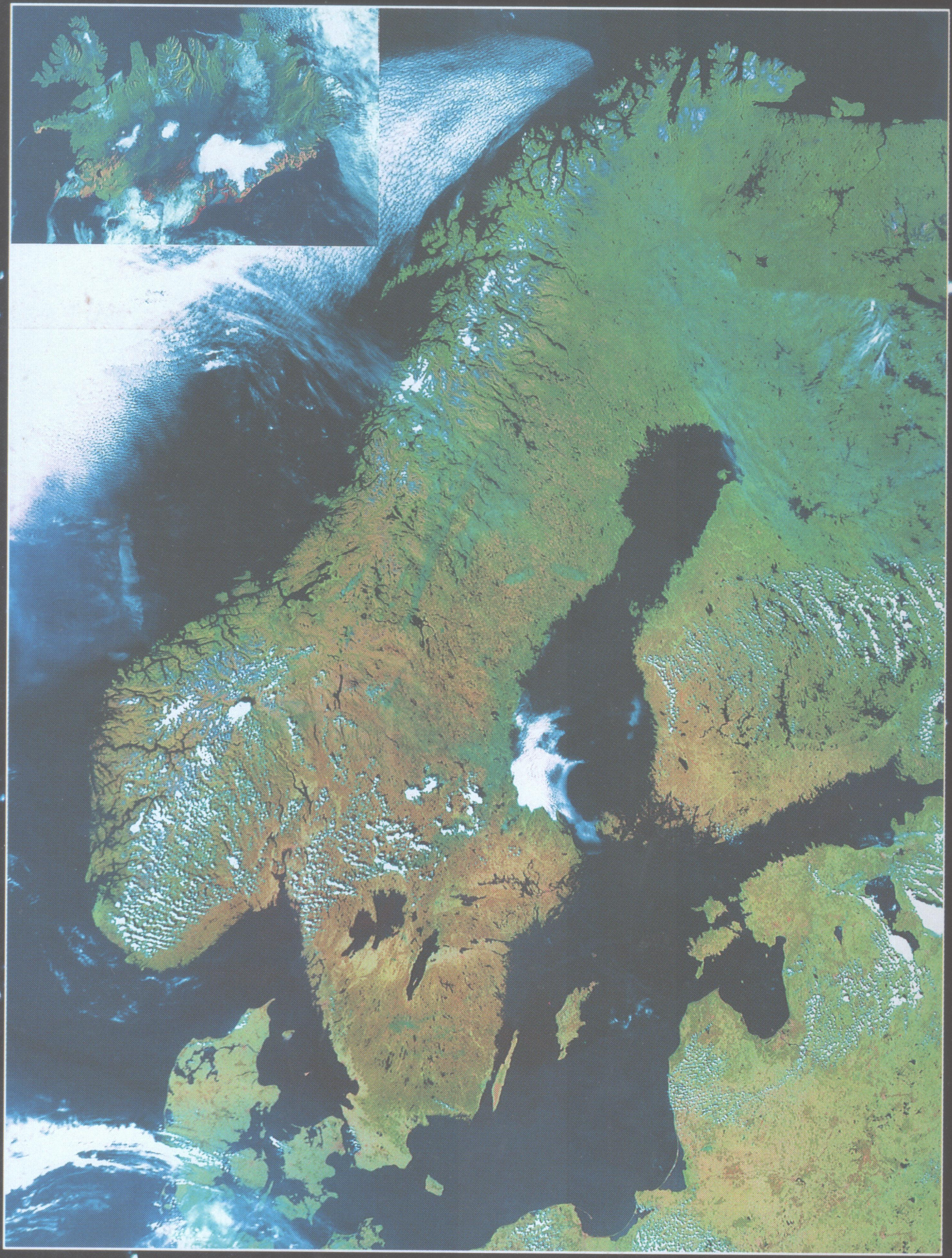

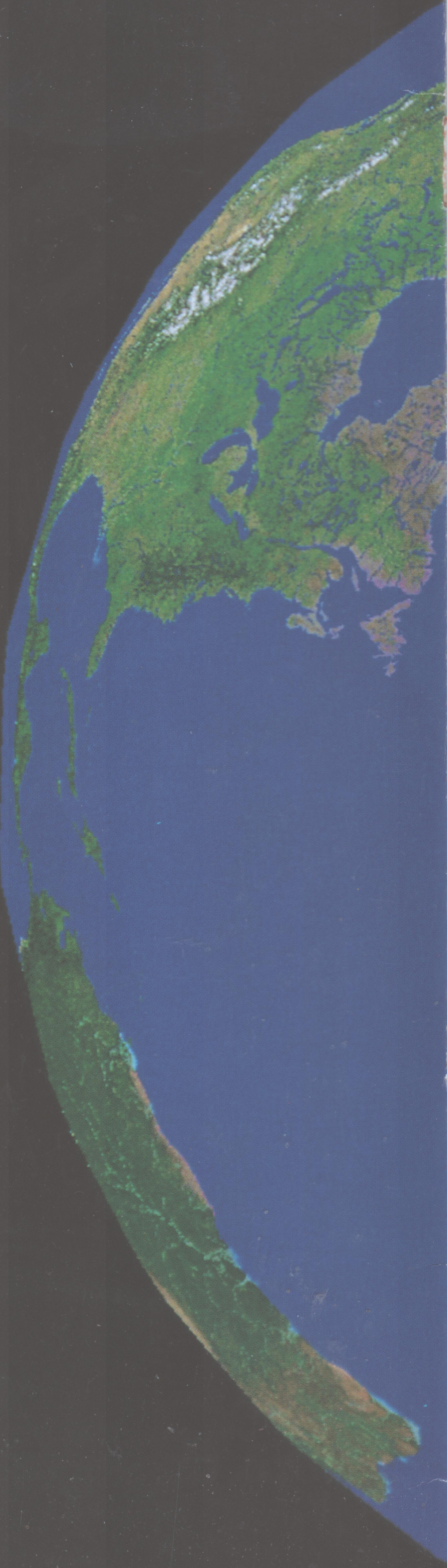

"We came from Earth,
from Dorisland
the jewel
in our solar system,
the only orb
where Life obtained
a land of milk
and honey.
Describe the landscapes
found back there,
the days those dawns
could bread".

From "Aniara" by Harry Martinson
(translated by Stephen Klass and Leif Sjöberg ©)

ERRATA

Page 12: The Landsat-image shows the town of Joensuu and its environment.

Page 20: The picture of Gran Canaria is upside-down and reversed.

Page 22: Second column, fourth line refers to the picture on the bottom left and the sixth line to the picture on the upper left.

Page 23: Second column, second line should read: yellow means 0-5 microgrammes per litre, etc etc. (Blue means land)

Back cover: The last sentence in the poem should read:
Describe the landscapes
found back there,
the days those dawns
could breed".